9th International Command and Control Research and Technology Symposium
Coalition Transformation: An Evolution of People, Processes, and Technology to Enhance Interoperability

KNOWLEDGE FOUNDATIONS OF EFFECTIVE COLLABORATION

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Knowledge Foundation of Effective Collaboration

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Abstract

In recent years collaboration has become increasing important. In the military, it is central to realizing the benefits of increased network connectivity as envisioned by the Office of Force Transformation and Network Centric Warfare. Effective collaboration contributes to better situation assessments, plans, and decisions. In operations, it enables force self synchronization.

For teams to be effective, they need adequate resources, adequate motivation, and the right kinds of knowledge. This paper addresses the knowledge foundations of effective collaboration. Summarizing four years of research sponsored by the Office of Naval Research, it describes both the kinds of knowledge important to team effectiveness as well as how teams employ this knowledge to coordinate, make decisions, and achieve consensus.

This fundamental cognitive perspective is now supporting multiple aspects of collaboration. It has helped generate metrics for evaluating collaboration and criteria for selecting collaboration tools. It has also provided the theoretical basis for an expert system to help teams diagnose and fix collaboration problems.

1. Collaboration and the Importance of Knowledge

In today's network-connected world, collaboration and teamwork are becoming increasingly important. Effective collaboration, both for co-located and spatially distributed teams, can improve the quality and timeliness of assessments and decisions. Effective teams can flawlessly synchronize, quickly adapting themselves to seize opportunities and thwart risks.

By integrating perspectives and drawing on the specialized expertise of its members, a team can outperform even the best of its individual members. For instance, in contrast to a single person planning alone, a collaborating planning team can generate:

- A better set of views on what is happening, the reasons for these occurrences, and their impacts on the team mission;
- A better set of candidate actions to take in response to these impacts;

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- A better set of criteria to consider when evaluating the desirability of these actions; and

- Better estimates of possible consequences of the alternatives being considered.

Because of these advantages, collaboration is a central part of the Network Centric Operations (NCO) Conceptual Framework (Evidence Based Research, 2004). In this framework (Figure 1), collaboration is the process that enables a robustly networked force to make better decisions. Collaboration, by enabling team members to leverage each others' experience, expertise, and imagination, improves situation awareness, understanding, and decision making.

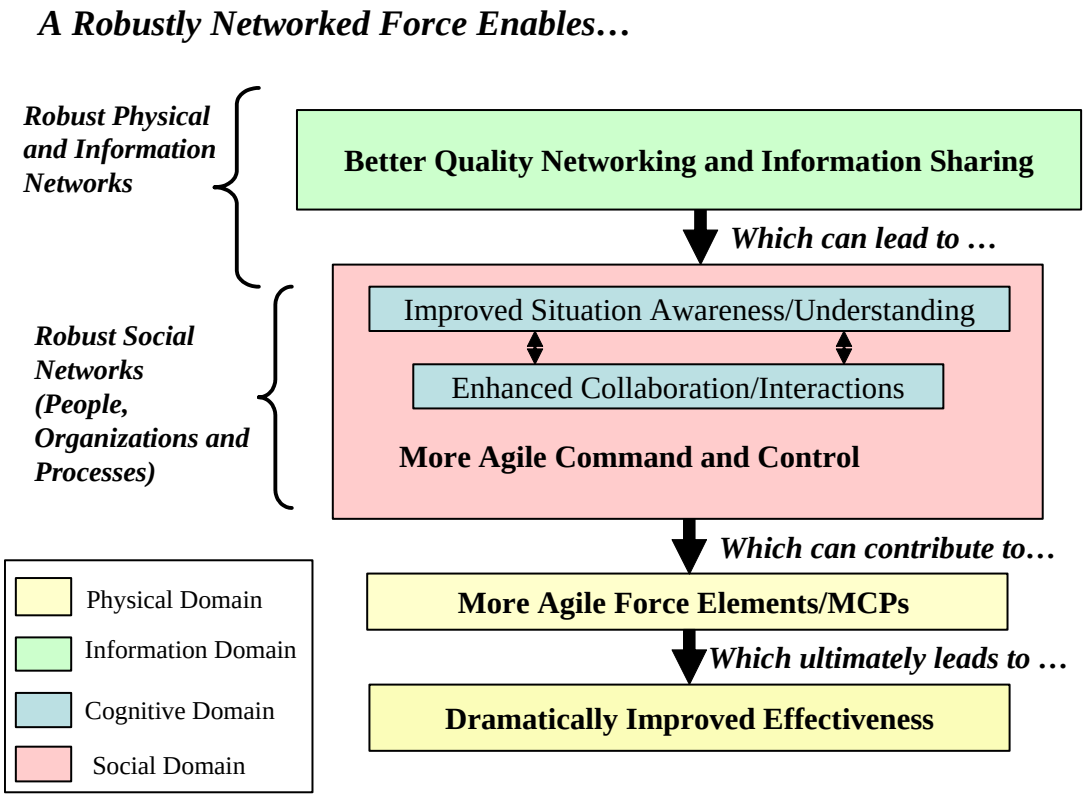


Figure 1. Collaboration Within the NCO Conceptual Framework

Unfortunately, collaborating teams are not always effective. They do not always identify viable alternatives for action, reach a good understanding of situation events, or generate high quality decisions. Though a team's failure is always undesirable, sometimes it can have disastrous consequences.

Teams can fail for one of three basic reasons: inadequate resources, lack of knowledge of what to do, or unwillingness to do the work. Much has been written about the first and third causes of failure (Maxwell, 2001; Katzenbach and Smith, 2001, Herbelin, 2000, Brounstein (2002). There has been much less discussion about the second cause, cognitive shortfalls. Yet, cognitive problems can be a team's undoing. A famous

example of this was the Kennedy administration's Bay of Pigs fiasco which was examined by Irving Janis (1972) in his classic "Groupthink." This operation attempted "to place a small brigade of Cuban exiles secretly on a beachhead in Cuba with the ultimate aim of overthrowing the government of Fidel Castro." The operation was an immediate military failure with all of the participants being either killed or led to prison camps.

This team did not fail because of inadequate resources and poor social interactions. This was a high motivated, extremely capable and knowledgeable cabinet level group that could draw on the full capabilities of the federal government. Instead, this team failed for cognitive reasons. The Kennedy team did not adequately focus on the full range of possible outcomes and did not anticipate some of the more harmful long-term effects of its actions. Team members were not aware of critical information that they needed to consider. Poor team business rules led to "poor sharing of information, unwillingness to share private information, suppression of personal doubts, and unwillingness to obtain outside information to test assumptions," and a "taboo about antagonizing valuable new members."

With a better understanding of these cognitive issues (Noble, 2004; Christie, 2004), it is possible the Kennedy team would not have failed. This paper describes a framework for understanding these issues. It also reviews a few of the ways that this framework is being applied to improve collaboration.

2. Premises and Overview

The starting point for describing the role of knowledge in effective collaboration is the following four basic premises. These outline the most important premises in this knowledge-centered theory of collaboration.

1. Knowledge is central to collaboration and teamwork. Teams whose members know what they need to know can work together effectively. Those that do not are prone to various kinds of predictable errors, with the type of error dependent on the type of knowledge deficiency. (Liang, 1995)

2. Knowledge must be distributed among members of a team. Everybody does not need to know everything for a team to be effective. But every team member does need to know how to get the knowledge he or she needs. (Wegner, 1987)

3. Individuals need to know about both "taskwork" and teamwork. Teamwork knowledge is what team members need to know to work together effectively . Taskwork knowledge is what team members need to know accomplish their part of the team's tasks. (Canon-Bowers, 1993)

4. The collaborative dialog helps generate the needed teamwork and taskwork knowledge. Team members exchange ideas to put in place the knowledge and understandings that team members must have for the team to achieve its mission. (Argote, 2000)

The first statement, that team members cannot work together effectively if they do not have the knowledge needed to do so, is our basic premise, and as written is almost a tautology. The following section briefly reviews what that knowledge. Other references describe this knowledge in greater detail (Noble, 2004) and what can happen when it is missing. The second statement, that team members do not personally need to know all critical knowledge but do need to know who to ask to get the knowledge, is the basis of "transactive memory." Sharing the responsibility for keeping track of various kinds of information is one of the biggest advantages of teamwork. The third item emphasizes that all teams are really working on two basically different kinds of issues: (1) creating their task's products or performing task actions, and (2) maintaining team relationships. It is not enough for every team member to be an expert in their individual jobs for the team to succeed; team members also need to know how to work together. The last item addresses how team knowledge builds on itself. In teamwork, there is a kind of self reinforcing cycle. Knowledge is needed for teams to work together effectively, but teams need to work together in order to obtain this knowledge.

Figure 2 illustrates the relationship between knowledge (the "individual and shared understandings") and some key team activities: "team set up and adjustment," "group problem solving," and "synchronize and act." This diagram helps show how knowledge success begets success and small failures grow into big ones.

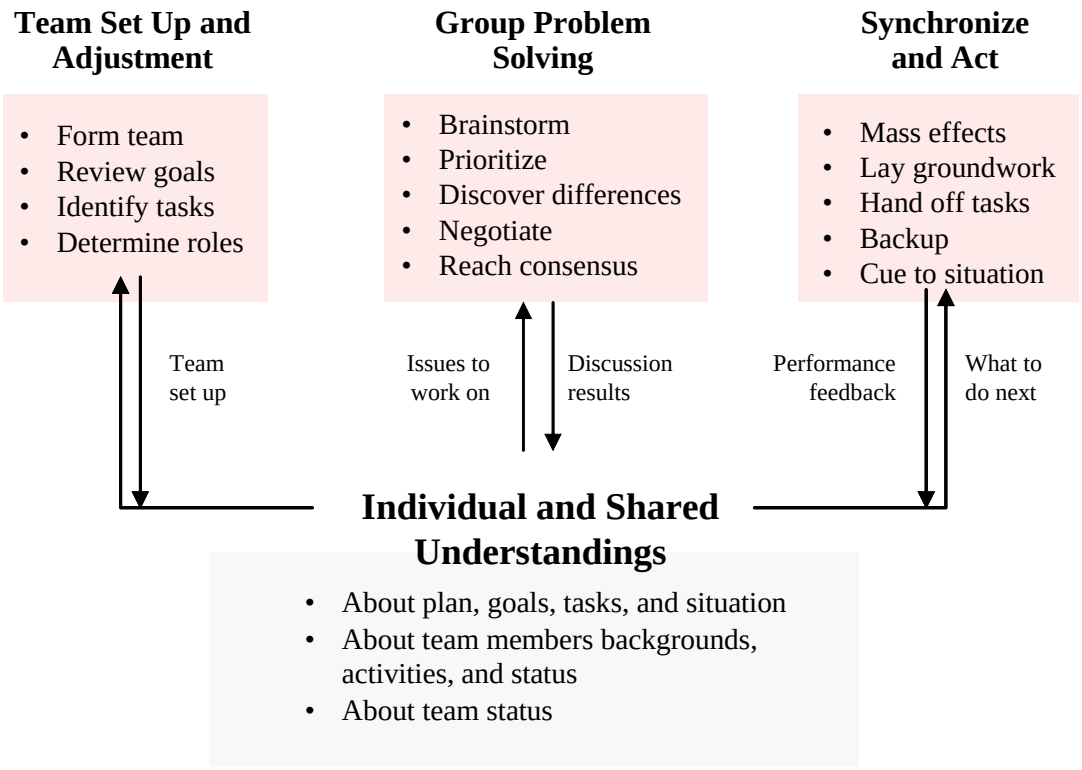


Figure 2. Relationship between Knowledge and Team Activities

All teams perform all three of these activities, generally moving from left to right but also switching back and forth among activities according to their immediate needs. In "set up and adjustment" the team organizes itself, reviewing goals, allocating roles and tasks, and defining the team's business rules. In the process of doing this, they generate and deposit critical team knowledge about goals, tasks, roles, and team interaction methods. Some of this knowledge may be written down in team documents, but much of it will reside as tacit knowledge in team members' minds. Team members need this knowledge when they carry out their "group problem solving." Here they identify and critique different issues, discover differences and align understandings, negotiate, and reach consensus about the nature of the problem and what they should do. When doing this, they draw on the knowledge acquired while performing earlier team tasks. As they progress, they refine and augment their knowledge with the results of their work. The same sequence also occurs with "synchronize and act." Team members draw on their knowledge to coordinate and help each other. They deposit knowledge about what works well and how they should interact as they work together.

This work-knowledge relationship can generate highly damaging action-knowledge cycles. A small amount of missing knowledge can undermine a team activity that creates information critical to later team functions, and when missing, causes these later functions to fail. Thus, it is important for teams to catch these small knowledge gaps quickly, before they grow and cause significant damage. One of the applications of this theory, an expert system for diagnosing and fixing team cognitive problems, helps team identify such knowledge gaps.

3. The Knowledge Teams Need

There is a vast amount and diversity of concrete knowledge—all of which can be critical to team effectiveness under some conditions. This knowledge includes, for example, knowing the team's goals and plans, how one task impacts another, where team members agree and disagree, and the team's rules for sharing information. In order to help people be aware of all of the different types of knowledge important to team success, we have organized the needed team knowledge into twelve "knowledge enablers." The first six, "team preparation," comprise the foundational knowledge that tends to build and change slowly over time. This is the knowledge that accounts for team members being able to work together more effectively as they get more experience working together. The second six, status assessment and decisionmaking, are the "real time" knowledge and understandings that can change dramatically instant to instant. This is the knowledge and understandings that enable people to react quickly to changing circumstances.

The twelve enablers are:

1. **Goal understanding** encompasses understanding team mission, the goals of the client, the criteria for evaluating team success, and the criteria for evaluating task progress. Understanding of team objectives includes understanding both the explicit and implied goals of the team, taking into account the cultural norms of the tasking authority. Goal understanding may be the most important of the knowledge enablers, for teams that do not know their goals are unlikely to achieve them.

2. **Understanding of roles, tasks, and schedule** is the "surface" understanding of the plan. Project plans usually decompose the team's work into separate tasks, assign these tasks to individuals or groups of people, and then specify a schedule. The plans may specify team member responsibilities, to include both fixed and context dependent leadership roles, principal task performers, and task backups.

3. **Understanding of relationships and dependencies** is the "deeper" understanding required to project success and make adjustments between tasks, resources, time, information, and the situation. The dependencies that are important to understand are the temporal, spatial, and causal (logical) relationships between separate tasks and between tasks and goals, information, resources, and the external situation. This understanding enables team members to predict the consequences of resource or information shortfalls, or of inadequately performed or delayed tasks.

4. **Understanding of team members' backgrounds and capabilities** includes knowing other team members' values and decision criteria, their capabilities and knowledge, and their level of interest and engagement. This knowledge enables other team members to predict what people can and will do under various circumstances. It is the cognitive basis of trust.

5. **Understanding of team "business rules"** includes both formal and unspoken rules by which team members work together. These are the rules for (1) talking, listening, brainstorming, and hearing outside perspectives at meetings; (2) critiquing and editing; (3) offering/asking for help and information; (4) providing performance feedback; (5) setting up meetings (how to schedule, who to invite); and (6) cc'ing and broadcasting. Poor business rules contributed significantly to the Bay of Pigs failure described earlier.

6. **Task knowledge** is the knowledge team members need to do their individual tasks. No matter how effective their teamwork is, teams cannot be successful if the individual team members lack the skills and knowledge to carry out their parts of the job. Task knowledge includes knowing how to perform assigned tasks, how to find and access documented information, how to use support tools, and how to find and access people with needed knowledge.

7. **Activity awareness** is knowing what others are doing, how busy they are, their level of engagement, if they are getting behind or over their heads, and if they need help with their workload. Activity awareness, sometimes called "team transparency," is essential for catching team problems quickly and for enforcing individual accountability.

8. **Understanding of the external situation** is appreciation of everything outside of the team that can impact its work. In military operations it includes the actions of the adversary. In business it may include the actions of competitors and the preferences of customers. Understanding the external situation includes knowing who the significant players are and knowing their status, capabilities, strengths, weaknesses, behaviors objectives, and plans.

9. **Task assessment** is determination of what tasks are being worked on and by whom, the status of these tasks, comparison of this status with the status called for by the plan, and judgment of the adequacy of available information and resources. It includes an assessment of progress and prospects for task success, including an estimate of whether a task needs help and whether required resources and information are available. Task assessment allows everyone on the team to dynamically adjust their work when other tasks progress either better or worse than planned.

10. **Mutual understanding** addresses the extent to which team members know how well they understand each other. It includes the extent to which team members are aware of where and why they agree or disagree about team goals, team progress, the external situation, and all the other team knowledge enablers. It does not include everyone agreeing on everything. There is no requirement that all team members always agree. There is a requirement however that they know when they do not agree.

11. **Plan assessment** is an estimate of whether the current team, processes, plans, and resources will still enable the team to achieve its objectives. It builds on and integrates assessments of team activities, task progress, the external situation, and degree of mutual understanding. Unlike a task assessment, which focuses on how well individual tasks are progressing, plan assessment considers all current factors and projections into the future to estimate the need for plan adjustments. Plan assessment is essential to teams adapting to changing circumstances.

12. **Understanding of decision drivers** includes grasping all of the factors that must be considered when making a decision. These include knowing what can impact the effectiveness of a decision, knowing the decision deadlines, picking the right strategy for decisionmaking under uncertainty, and knowing who should be consulted when deciding what to do.

Of course, these twelve enablers are not the only way to organize needed team knowledge (Mathieu, 2000). After numerous case studies and extensive literature review, we chose the twelve to be described above because they (1) provide a level of diagnosis that points to concrete actions able to improve team performance; (2) are easy to understand; (3) map reasonably cleanly onto risks and symptoms of team problems, and (4) as a set, account for key team behaviors, such as team agility, team member backup, accountability, and coordination. The Collaboration Advizor™ Tool, the expert system that helps teams diagnose and fix knowledge-based collaboration problems, builds on this organization of knowledge. This organization has worked well for this tool. All five of the teams that tested the tool at the time have found this knowledge organization useful.

Another attractive aspect of these enablers is that they generalize in a natural way Command and Control processes described for individuals (e.g., the Headquarters Effectiveness (HEAT) model as described in Noble and Kirzl, 2003) to more encompassing processes applicable also to teams. Several of the enablers—task skills, plan assessment, and the understandings of goals, the plan, dependencies, the external

situation, and decision factors—are as essential to individual work as to teamwork. The detailed knowledge for these enablers differs very little from that required for individual performance. Several others of the enablers apply only to teams and are not relevant to an individual working alone. These are the enablers for understanding others, team business rules, activity awareness, and mutual understanding. One enabler, "current task assessment" is not only important when working alone, but also imposes significant additional knowledge requirements in a team setting.

The full description of this needed team knowledge (Noble, 2004) describes these enablers in much greater depth. It provides for each a more complete description of the knowledge elements, the possible consequences to a team should the knowledge be missing, impediments for obtaining the knowledge, and symptoms for not having it.

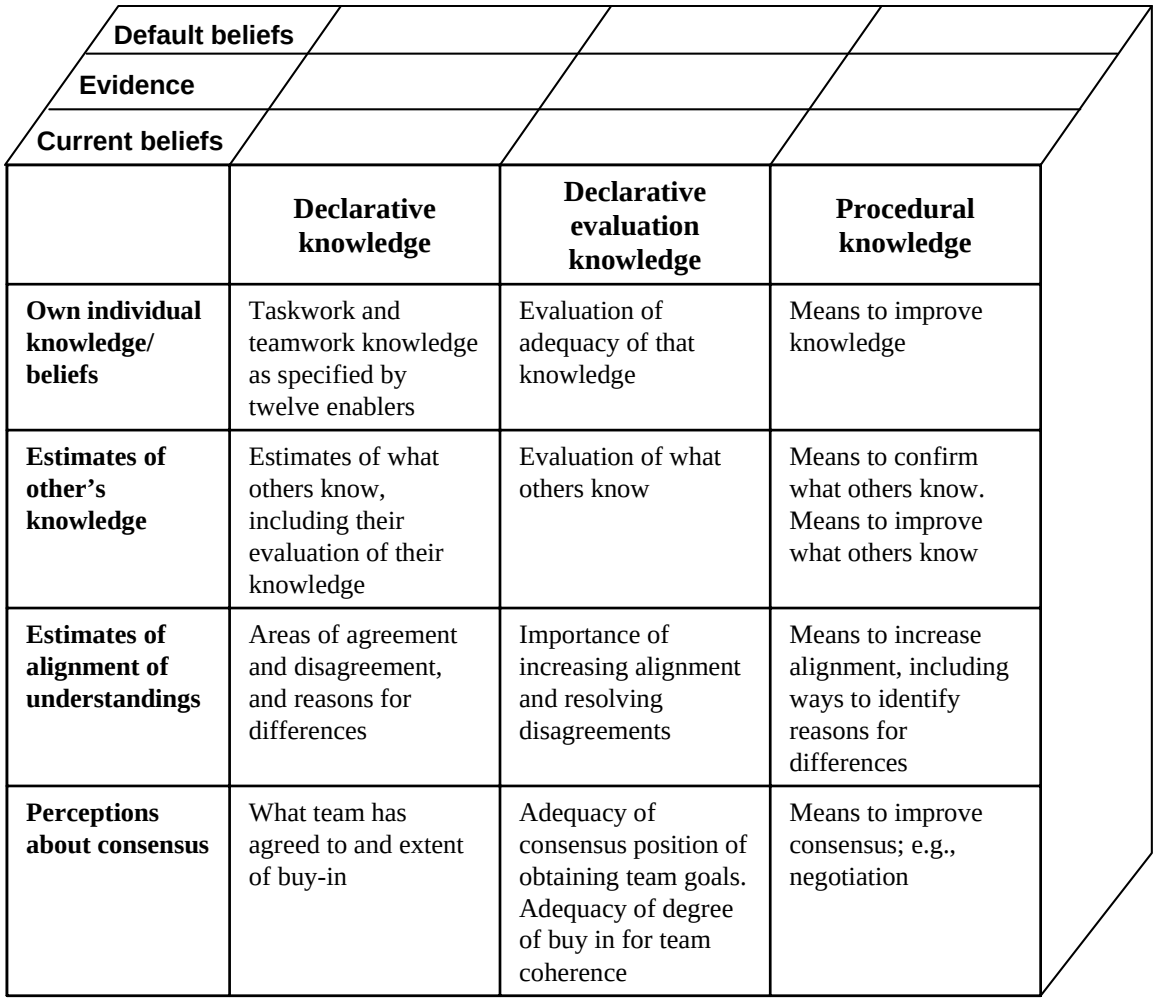
However, even the simplified description in this paper can help teams diagnose and fix problems. Just being aware of the fact that a team's problems may have cognitive causes and then considering which of these twelve enablers might be responsible can trigger ideas about how to fix the problems. If the team does not understand its goals, it can have a meeting to discuss its objectives and the constraints that must be observed. If two people do the same work unnecessarily and the team thinks the problem was a poor understanding of the plan, then the team can meet to review the plan, post the plan in a prominent place, or draw a diagram summarizing team members' responsibilities. If the team thinks that the cause of the redundant work was poor activity awareness, then it can arrange to have team members make periodic progress reports to each other. It can also set up a central repository for team members to post their products.

4. Evaluative Knowledge and Team Processes

The previous section described the types of concrete knowledge that team members need in order to accomplish their tasks and coordinate. In addition, team members need evaluative knowledge in order to decide when to acquire or share information, help one another, question or accept team consensus positions, change the plan or team processes, and make decisions.

Team members make these process decisions when they see a need to. Our formal model for such team decision making has been called *opportunistic control* in the artificial intelligence literature because there is no set sequence in which the team members decide when to share or ask for information, offer or ask for help, negotiate and seek consensus and make decisions. Instead, each team member takes these occasions when they decide doing so would help themselves and their team.

To make opportunistic control work, team members need to have the different kinds of knowledge shown in Figure 3. When they have this knowledge, the team will have the "cognitive glue" that generates what is sometimes referred to as a "team mind." Note that this "team mind" is just a metaphor. All the team knowledge in a "team mind" actually resides in the minds of the individual members. Thus, every team member has his or her own version of the knowledge in Figure 3 that reflects what that individual person believes.



	Declarative knowledge	Declarative evaluation knowledge	Procedural knowledge
Own individual knowledge/ beliefs	Taskwork and teamwork knowledge as specified by twelve enablers	Evaluation of adequacy of that knowledge	Means to improve knowledge
Estimates of other's knowledge	Estimates of what others know, including their evaluation of their knowledge	Evaluation of what others know	Means to confirm what others know. Means to improve what others know
Estimates of alignment of understandings	Areas of agreement and disagreement, and reasons for differences	Importance of increasing alignment and resolving disagreements	Means to increase alignment, including ways to identify reasons for differences
Perceptions about consensus	What team has agreed to and extent of buy-in	Adequacy of consensus position of obtaining team goals. Adequacy of degree of buy in for team coherence	Means to improve consensus; e.g., negotiation

Figure 3. Knowledge Categories Important for Team Decision Making

This model organizes knowledge along three dimensions. The horizontal axis is the declarative and procedural knowledge that team members need in order to work together effectively. The vertical axis groups knowledge in ways related to consensus and alignment. The third dimension, the axis into the page, addresses team members' current beliefs and the reasons for team these current beliefs. Note that in the absence of evidence, team members will assume their defaults while hedging for other possible interpretations.

This model identifies three kinds of knowledge along the horizontal axis. It makes the usual distinction between declarative knowledge (e.g., facts) and procedural knowledge (how to do things). Within declarative knowledge, it distinguishes between estimates of what is vs. the "image" of what the team member would like the status to be (Beach and Mitchell, 1987). Comparing the status of the team and tasks with beliefs about what the status should be is extremely important to any decisions about changes that need to be made.

The vertical axis is perhaps the most important for understanding the relationship between knowledge and collaboration-related team member decisions to acquire or share information, to seek consensus, or to flag needed team adjustments.

The first row, "own individual knowledge/beliefs," is most important for decisions about acquiring information. This row includes what every team member believes to be true about the task, external situation, plan, goals, etc., the "meta knowledge" that people have about the adequacy of this knowledge, and knowledge about how to get more information. People decide to get more information when they believe their current information is inadequate. The second row, "estimates of others' knowledge," is most important for decisions about sharing knowledge and informing others. People inform others when they think that another person needs additional information. The third row is most important for initiating discussions about the nature of a problem or situation. In our collaboration model, it is not important that all team members agree on all issues. However, sometimes it is important that team members agree on a particular issue. This is the row that enables people to decide when its worthwhile to try and resolve a difference in viewpoints. The fourth row is the most important for decisions about when to discuss consensus. It supports decisions about when to discuss what the team's positions should be.

The knowledge on the axis into the page is especially important when team members estimate what others know and when they decide how to discuss differences in viewpoint. People estimate what others believe from estimates about the information ("evidence" in Figure 3) that they have received and from what these people tend to believe in the absence of information (their "default" beliefs). Resolving differences in viewpoint often requires discussing not only the information each person has received, but also each person's pre-disposition to adopt various positions.

5. **Applications**

This perspective on knowledge foundations for effective collaboration described in this paper has four practical applications. It generates metrics and a methodology for evaluating collaboration. It provides a way to diagnose and fix collaboration problems. And it suggests how to evaluate and select collaboration tools and to allocate roles within a team, including teams composed of both people and computer agents. The following summarizes each of these applications. Each of these is discussed at length elsewhere.

1. Metrics and evaluation methodology (Noble and Letsky, 2002, Kirzl et al, 2003, Noble and Kirzl, 2003). This knowledge framework suggests four classes of metrics: on product quality or action effectiveness, on critical team behaviors, on team knowledge, and on infrastructure impediments to knowledge. The combination of metrics enables evaluators to measure the impact of an intervention (e.g., new collaboration tool) on team performance and to understand the reasons for this impact.

2. Diagnosing and fixing problems (Noble, 2004a). By describing the impediments to team knowledge and the symptoms of knowledge shortfalls, the theory helps

teams diagnose problems. Building on this foundation, Evidence Based Research created a Collaboration Advizor™ tool that teams use to diagnose and fix problems. This tool has been used successfully for several types of collaboration teams.

3. Selecting and evaluating tools (Noble, 2004b). Collaboration tools include not just tools to improve communication (e.g., e-mail, chat, VTC), but also tools to help teams manage and structure information and support team processes. Most collaboration tools help teams by facilitating acquisition and maintenance of knowledge important to effective collaboration, or by reducing impediments to the knowledge. By identifying these knowledge areas and impediments, the theory helps tool selectors understand more precisely how various kinds tools can help their teams.

4. Allocation of team roles (Noble, 2003a and 2003b). Roles are best assigned to the people or computer agents that know how to carry out these roles. By specifying the knowledge and judgments that various roles require, this foundation helps team organizers to make these assignments. For example, all roles require an understanding of team goals but only some roles also require an understanding of implicit social, cultural, and organizational constraints associated with these goals. Roles that requires understanding such implicit constraints should be assigned only to people and not to computer agents.

6. Summary

By enabling team members to leverage each others' perspectives, experience, expertise, and imagination, collaboration facilitates generation of superior situation assessments, plans, and decisions. Because it allows the military to take advantage of network connectivity, it is an important element of Network Centric Operations.

While collaboration is potentially highly beneficial, not all teams are effective. Sometimes when they are not, the problem is cognitive. Team members do not know what they need to know in order to work together effectively.

This framework for understanding the knowledge foundations for effective collaboration describes the specific kinds of knowledge that teams need for effective teamwork, organizing this knowledge into twelve "knowledge enablers." It also describes the kinds of "meta-knowledge" (evaluative knowledge) that team members need in order to decide when to acquire or share information, when to discuss issues, and when to correct team problems.

This framework can improve teamwork by suggesting metrics and techniques for evaluating collaborating quality and identifying specific causes of collaboration problems, by suggesting ways to select collaboration tools, by helping teams diagnose and fix problems, and by helping organizers allocate people and computers to team roles.

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Topics

- What collaboration is and how it fits into NCW
- Why teams fail, with some famous examples
- How collaboration works
- What people need to know, and what happens if they don't know
- Applying cognitive focus

A Definition
Expert Leverage Focus

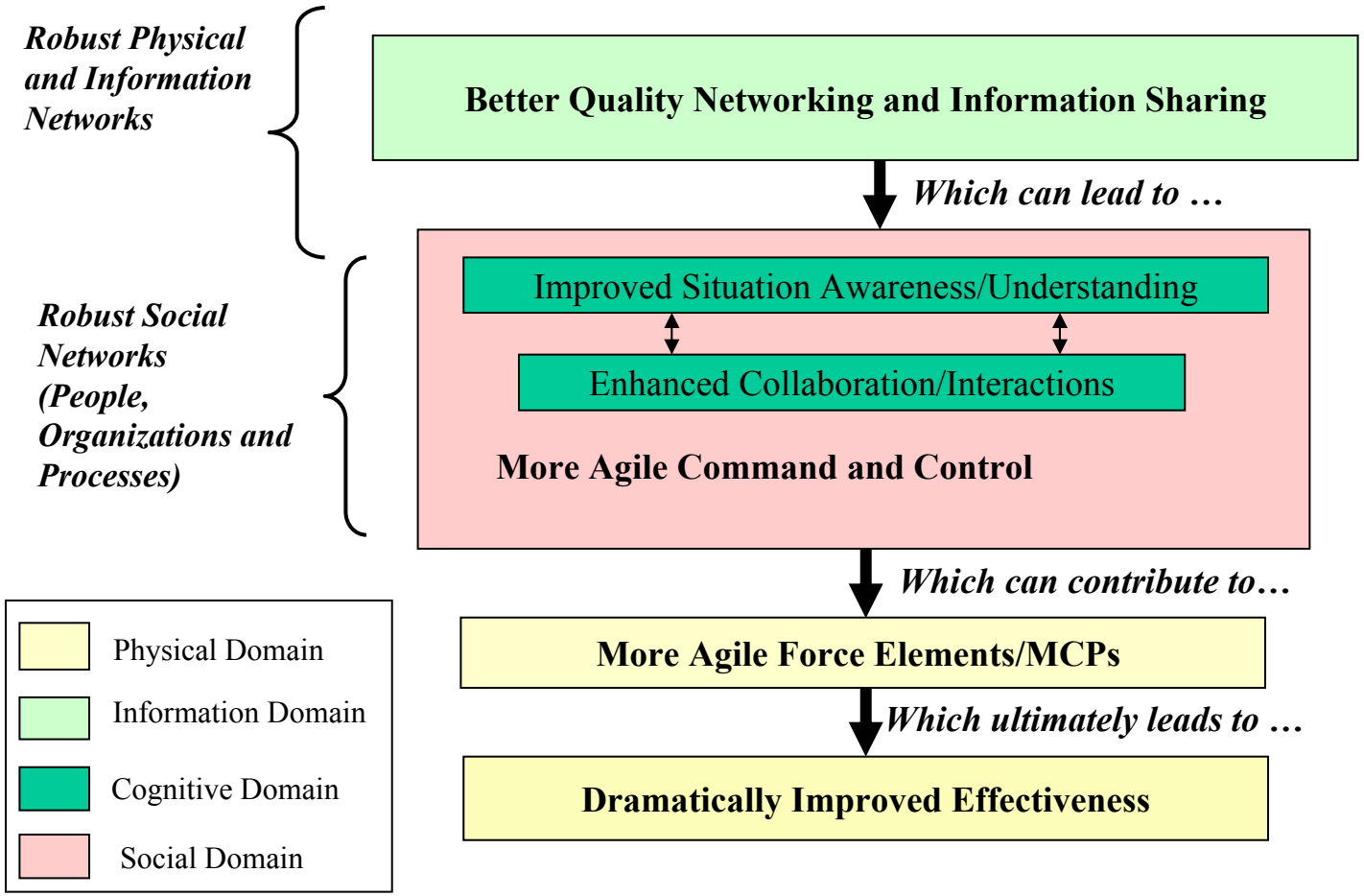
- Experts integrating perspectives to better interpret the situation and problem, identify candidate actions, formulate evaluation criteria, and decide what to do
- By collaborating, the team comes up with a better solution than any one team member could working alone

Group Problem Solving
Sharing of Perspectives

- Collaboration enables teams to "make better lists"
  - Better views on what is happening, the reasons for these occurrences, and their impacts on the team mission
  - Better set of candidate actions to take in response to these impacts
  - Better set of criteria to consider when evaluating the desirability of these actions
  - Better estimates of possible consequences of the alternatives being considered

Collaboration Within the NCO Conceptual Framework

A Robustly Networked Force Enables…



Why Collaboration Fails

- The problem's too hard for our team to succeed
  - EBR decides to form a basketball team, with the goal of beating the Lakers next year
- The team doesn't know how to succeed
  - We'll have a curling team instead, with goal of winning a game in Vienna. But the team doesn't know how to organize and train
- The team members don't care about the goals and don't want to do the work
  - Who wants to do curling anyway. We want to play pinochle instead

Famous Examples of Cognitive Failures

The Bay of Pigs, 1962

A talented and intelligent policy team, but Groupthink doomed the team to an unworkable plan with disastrous results

The Iranian airline shootdown, July 3, 1988

Well trained team on Vincennes, but misunderstandings of each others information and perspectives led to a tragic mistake

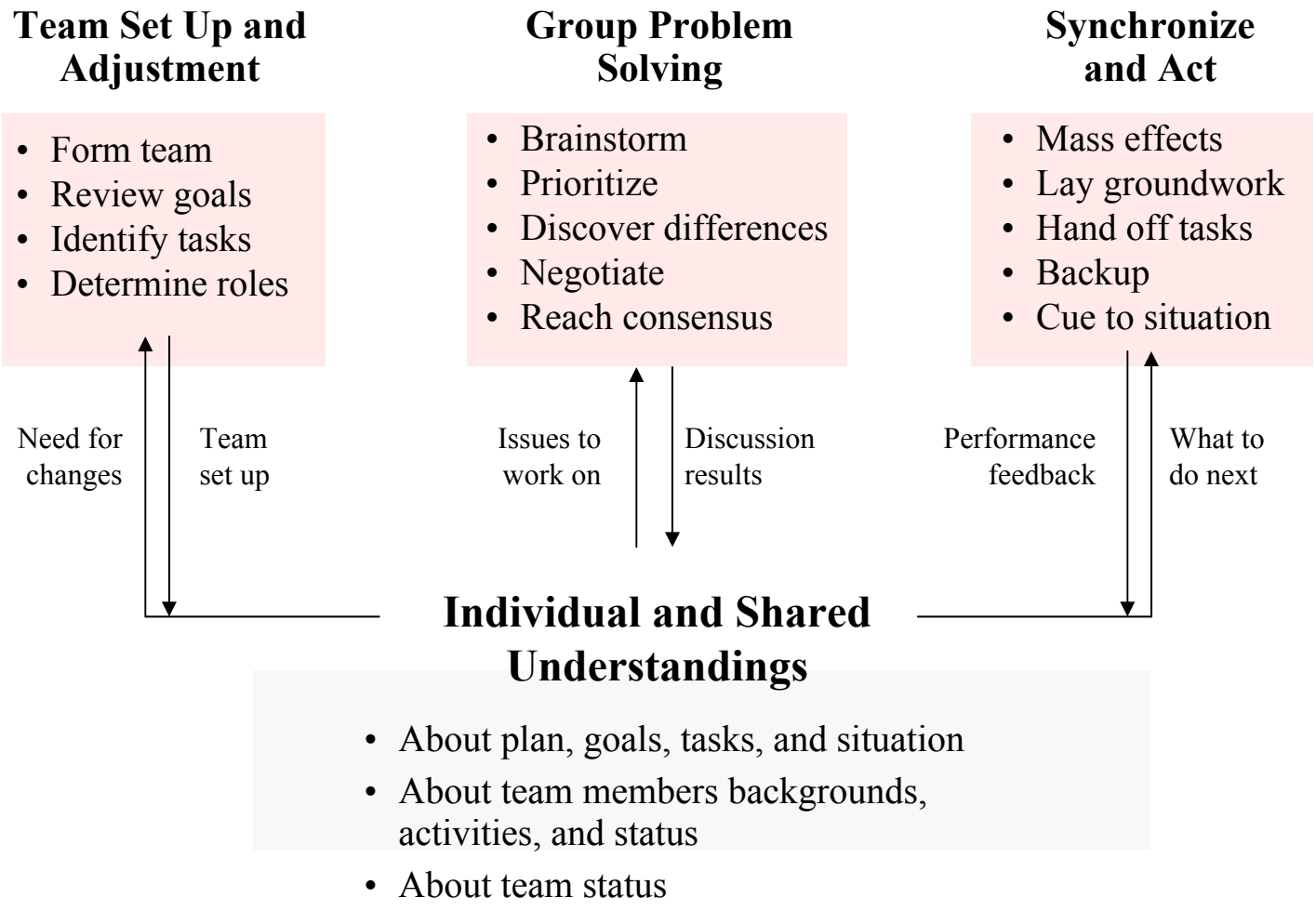
How Collaboration Works
Knowledge-Centered Collaboration Theory

- Theory
  - Specifies the knowledge team members need to interact effectively for the benefit of the team
- Applications
  - Methodology for educating team members on teamwork, tracking team progress, alerting to problems, and recommending solutions
  - Assessing improvements to collaboration and teamwork after introduction of new tools, processes, or organization
  - Selecting collaboration tools
  - Allocating knowledge responsibilities among team members, both human and computers

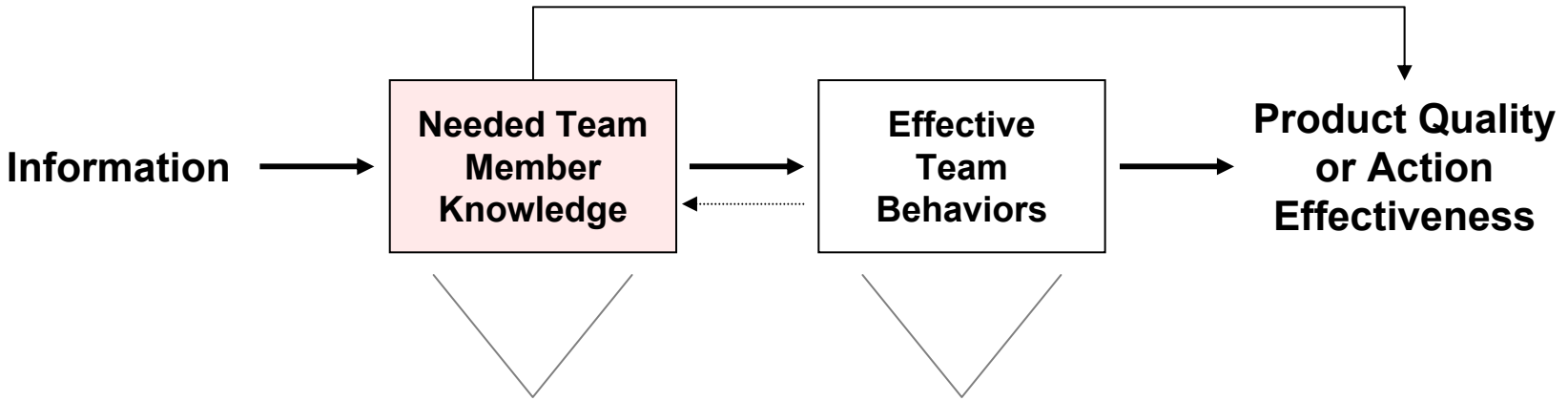
Premises
Knowledge Basis for Collaboration

- Knowledge is central to collaboration and teamwork
  - Teams whose members know what they need to know can work together effectively. Those that do not are prone to various kinds of predictable errors, with the type of error dependent on the type of knowledge deficiency
- Knowledge must be distributed among members of a team
  - Everybody does not need to know everything for a team to be effective. But every team member does need to know how to get the knowledge he or she needs.
- Individuals need to know about both "taskwork" and teamwork
  - Taskwork knowledge is what team members need to carry out their tasks were they acting alone
  - Teamwork knowledge is what team members need to know to work together effectively
- The collaborative dialog helps generate the needed teamwork and taskwork knowledge
  - Team members exchange ideas to clarify issues and reach consensus to put in place the knowledge and understandings that team members must have to achieve the team's mission.

Building Blocks of Collaboration and Teamwork



The Central Role of Knowledge



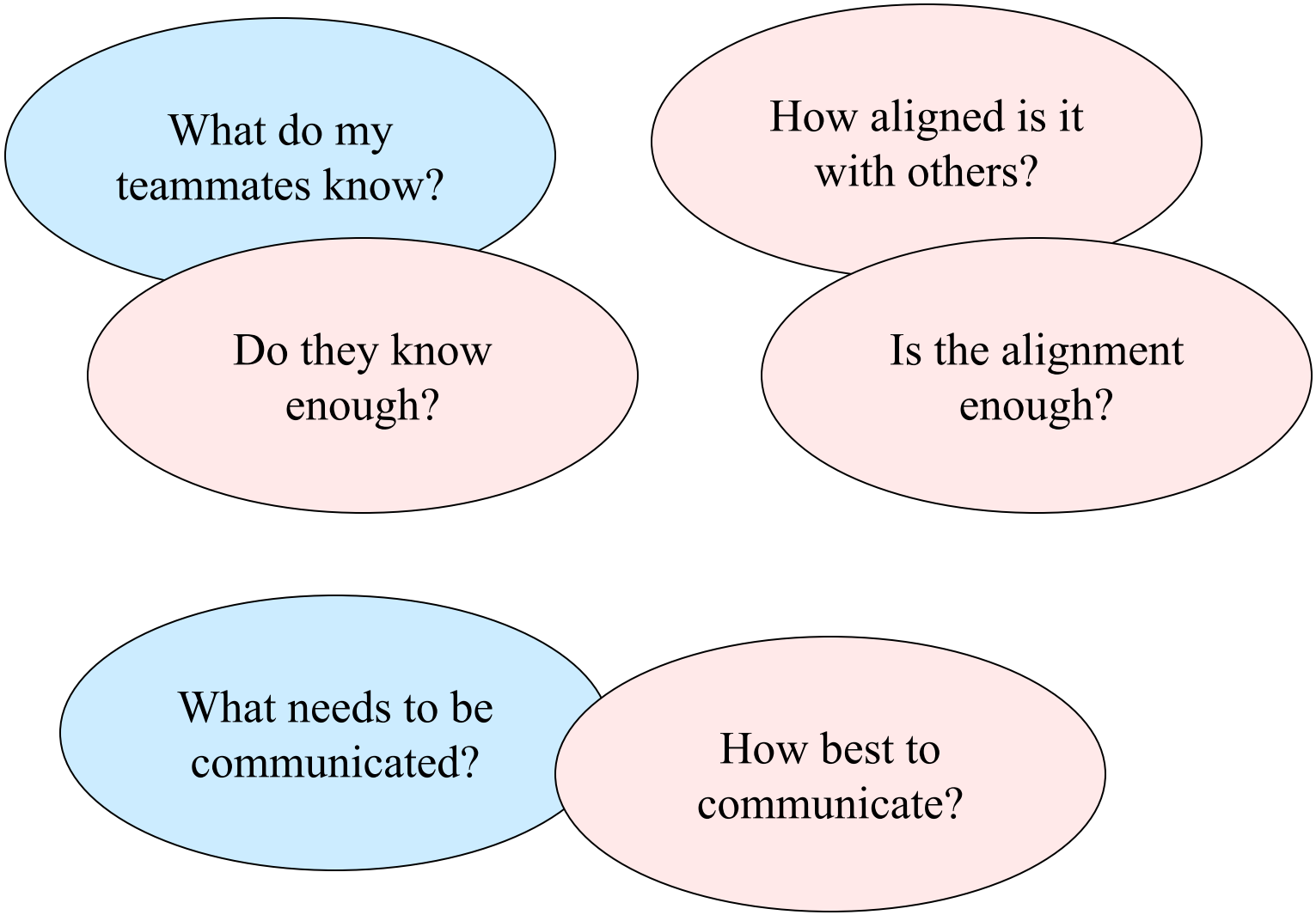
The twelve knowledge enablers

What team members need to know to work together effectively

Team synchronization:

Well oiled machine or Keystone Cops?

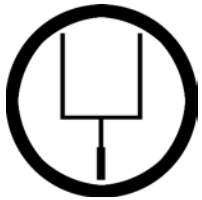
Evaluative Knowledge—the Basis of Team Cognitive Glue



The Twelve Enablers

- Represents basic cognitive foundations for effective collaboration
- At a level useful for diagnosis and recommendations
  - Deficiencies in enablers are the underlying causes of teamwork problems
  - Risks and symptoms map easily to enablers
  - Recommendations follow directly from them
- Generalizes well known critical C2 and decision functions for teams

Knowledge Enablers
Foundational Knowledge



Goals

Others

Plans

Business rules

Dependencies

Task skills

Knowledge Enablers

Real Time Understanding and Assessments

Activity Awareness

Mutual Understanding

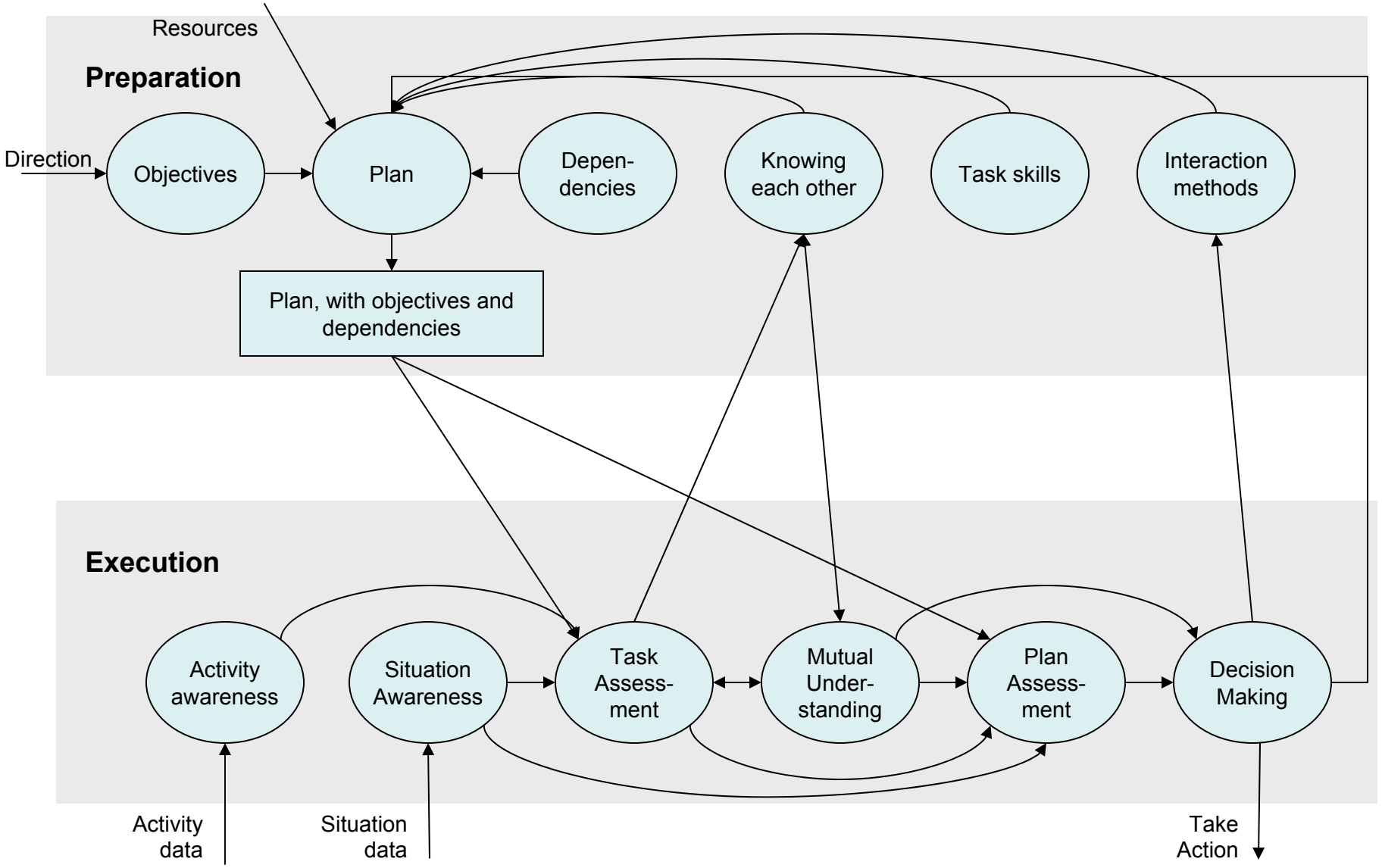
External Situation

Plan Prospects

Task Progress

Decision Factors

Principal Enabler Dependencies



Some Consequences of Knowledge Gaps

A team that doesn't know where it's going may have difficulty getting there

Chaos

Can't prioritize work or predict results of actions

People let them down and lose trust in one another

Fights, hurt feelings, and people quitting the team

Failed tasks

People making mistakes keep making them

Can't react to a changing environment and to the actions of your competitors

Broken tasks don't get fixed

Team members work at cross purposes

Team keeps implementing a bad plan that can't work

Bad decisions, bad outcomes, and a failed mission

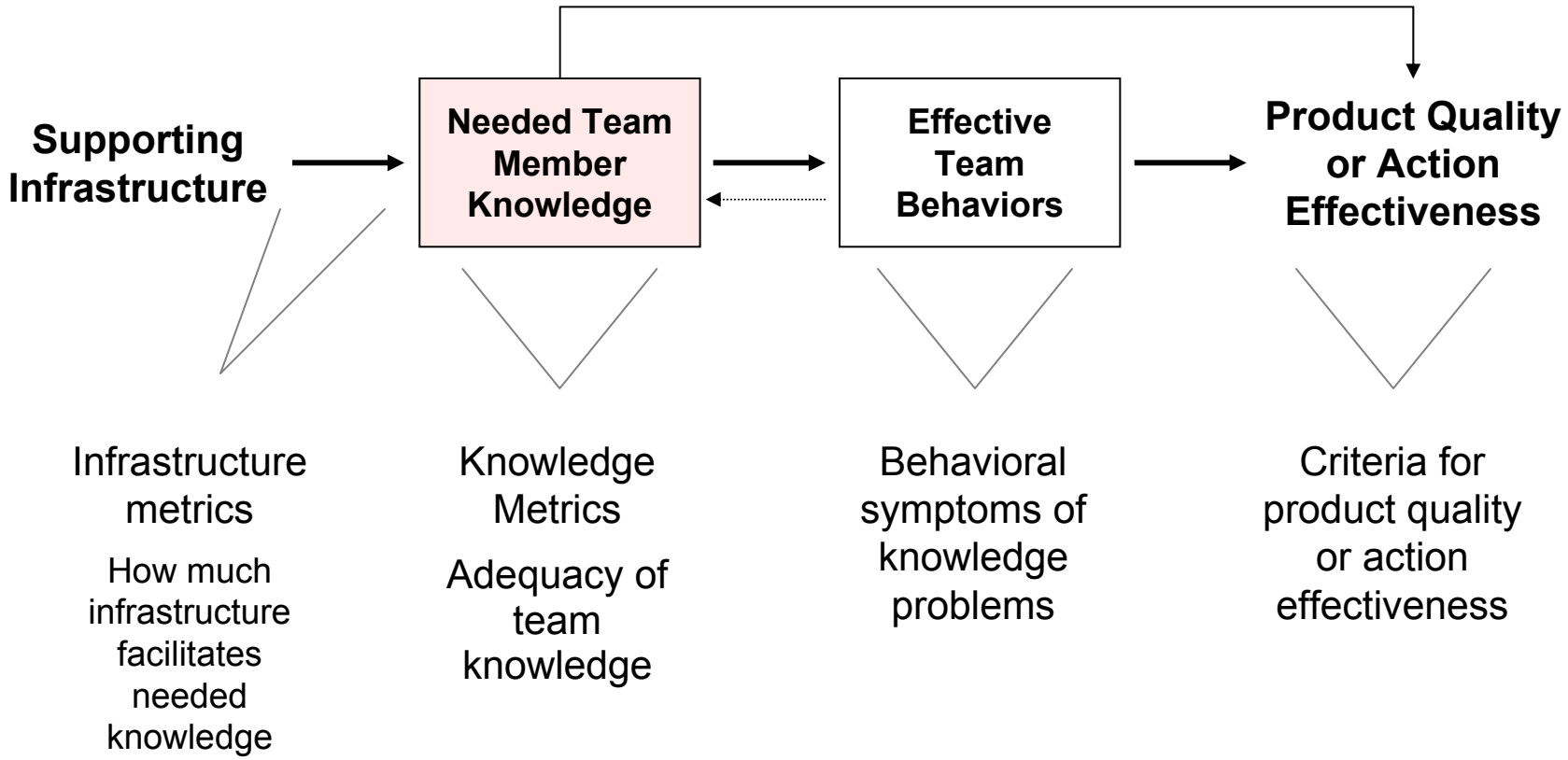
Applications

- Diagnosing and fixing problems
- Metrics
- Tool selection
- Computer/ robot rules

Diagnosing and Fixing Problems
Collaboration Advizor Tool

- Expert system software
  - Alerts to possible knowledge problems
  - Warns of consequences
  - Shows areas of agreement/ disagreement
  - Suggests ways to improve

Metrics*

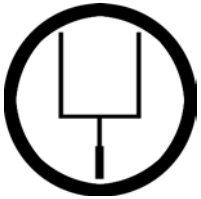


*Most extensively documented in "Command Performance Assessment System" (Kirzl, Noble, Leedom)

Knowledge-Based Tool Selection

- Communication (e.g., e-mail)
  - Common support to all knowledge areas
- Common awareness tools (e.g., COP)
  - Especially important for mutual understanding
- Knowledge and document management (e.g., common document repositories)
  - Task assessment, and indirectly helps gain knowledge of others
- Management support (e.g., project management tools)
  - Plan understanding, task and plan assessment
- Group process support (brainstorming tools)
  - Task assessment and business rules
- Shared development (shared applications)
  - Task assessment and activity awareness

Knowledge-Based Computer-Robot Roles

	Computers	People
 Goals	Explicit goals associated with concrete measurable objectives	Unstated goals implied by cultural norms
 Business rules	Rules for distributing information, accepting edits, enforcing formal permissions	Understanding reasons for rules, so know when to break them
 Mutual Under-standing	Extent of likely agreement/ disagreement based on shared information	Extent of likely agreement/ disagreement based knowledge of person

Summary

- Knowledge is essential to collaboration and teamwork
- Knowledge-Centered Collaboration Theory describes needed team knowledge
- Knowledge perspective supports
  - Diagnosing and fixing team problems
  - Collaboration metrics
  - Tool selection
  - Role allocation